Meeting the Challenge of Teacher Preparation

In 1998, the Department of Education established Teacher Quality Enhancement grants to encourage comprehensive approaches in improving the quality of teacher preparation programs. Many of these grants are five-year awards with cumulative multimillion-dollar funding. Twenty-five awards were made in fall 1999, and eight awards were made in 2000. Six of these awards were given to institutions that had already begun the process of reform under the National Science Foundation's Collaboratives for Excellence in Teacher Preparation (CETP) program, which was initiated in 1992.

The 32 systemic (regional in scope) and institutional (concentrated in one or a few related institutions) CETP projects awarded as of fiscal year 2000 included 250 institutions of higher education (13 percent of the projects related to doctoral degrees, 30 percent to two-year degrees, 31 percent to master's or bachelor's degrees) and 89 to public high schools.

Data collected in spring 2000 by the systemic projects reveal that 4,050 faculty and 4,979 teachers were involved in the CETP projects' efforts to produce teachers who are prepared to teach mathematics and science and to teach and use information technology. The institutions involved in the CETP program are distributed within 22 states and produce 38 percent of the teachers in the states in which they operate. Of the 15,896 1999 CETP graduates who have been tracked, 72.4 percent entered the teaching profession, and 17.7 percent were still attending school—most presumably in postbaccalaureate programs necessary for certification in their state (NSF/EHR 2000).

Evaluation of these programs has shown that, generally, the concerted efforts to improve teacher education in mathematics and science have been effective:

- Higher student achievement was measured in schools served by the Philadelphia CETP (Temple University). From 1996 to 1999, the Stanford Achievement Test (SAT-9) math and science average test scores and gains for 4th-grade classes in which CETP undergraduates taught during their practica exceeded the citywide average.
- Retention of new teachers in the Montana CETP Early Career Support project improved. The attrition rate from teaching for the more than 120 beginning teachers in the Early Career program was approximately 3 percent, far below the national average of 30 percent.
- An increase in minority teachers resulted from the efforts of the Montana CETP. In 1992, before CETP was instituted, 5 of the 1,500 mathematics and science teachers in the state of Montana were Native American. By the end of the project in 1999, 11 American Indians had graduated certified to teach mathematics or science, and 77 more were in the pipeline, attending tribal colleges or university campuses for secondary mathematics or science certification.

catalyze efforts to improve teacher preparation. See sidebar, "Meeting the Challenge of Teacher Preparation." Alternative certification programs to increase the nation's supply of math and science teachers are aimed at those already in S&E careers or S&E majors who would like to enter K–12 teaching (Feistritzer and Chester 2000; Urban Institute 2000). See sidebar, "Alternative Certification for K–12 Teachers."

National data are scarce with regard to how students go through higher education, the extent of participation, and learning outcomes. See sidebar, "Special New Programs," for information about some funding programs and institutions attempting to implement recommended reforms. Changes include focusing on learning outcomes in undergraduate education, increasing diversity of the S&E workforce, incorporating recent advances in teaching and learning into the undergraduate classroom, and augmenting research experiences for undergraduates.

Graduate S&E Students and Degrees in the United States

Overall Trends in Graduate Enrollment

Is the United States educating an adequate number of bachelor-level S&E majors who are willing and able to pursue advanced degrees in S&E? Has access to graduate programs improved for women and underrepresented minorities? This section presents trends in graduate enrollment: strong growth in foreign student enrollment until 1992 and declining enrollment for both U.S. and foreign citizens from 1993 to 1998. Enrollment of foreign students turned up considerably in 1999, increasing their proportion of the graduate population.

The long-term trend of increasing enrollment in graduate S&E programs in the United States persisted for several decades, peaked in 1993, declined for five years, and then increased in 1999. Trends differ somewhat across S&E fields. For example, enrollment in mathematics and computer sciences peaked in 1992, declined for three years, and then increased from 1995 onward. In contrast, the number of graduate students in engineering declined for six consecutive years (1993–98) before increasing slightly in 1999. (See appendix

Alternative Certification for K–12 Teachers

The use of alternative routes to teaching certification is controversial. Although some experts point out the benefits of more traditional programs such as the use of fifth-year certification programs as a route to alternative certification, they also question the value of short-term alternative certification programs. According to a report from the National Commission on Teaching and America's Future, evaluations of truncated alternative certification programs reveal that students of these teachers learn less than those taught by traditionally prepared teachers (Darling-Hammond 2000). In addition, the report shows that approximately 60 percent of individuals who enter teaching through such programs leave the profession by their third year compared with approximately 30 percent of traditionally trained teachers and only about 10–15 percent of teachers prepared in extended, five-year teacher education programs.

A contrasting view is that alternative routes attract a significantly higher proportion of minority candidates who are more willing to teach mathematics and science in urban and rural environments. Two examples are Troops-to-Teachers and Teach for America. Troops-to-Teachers enables military retirees to prepare to be teachers through existing teacher preparation programs (approximately 50 percent have entered through an alternative teacher preparation and certification program and 50 percent through traditional college-based programs). Since 1994, this program has brought 3,000 military retirees into the teaching profession. According to a recent survey conducted by the National Center for Education Information, Troops-to-Teachers graduates are more likely than the general teaching population to teach mathematics or science (respectively, 29 versus 13 percent teach mathematics and 16 versus 8 percent teach science), be members of minority groups (30 versus 10 percent), or teach in inner-city schools (24 versus 16 percent) (Troops-to-Teachers 2001).

Teach for America enlists liberal arts graduates directly out of college to teach in poor urban and rural schools for at least two years after a summer training period and an induction period at the beginning of the teaching experience. The program has recruited and placed more than 6,000 individuals in teaching positions; 58 percent of the alumni are still in education, of whom 40 percent are full-time teachers. In 1997, 17 percent of matriculants were mathematics and science majors, and 33 percent were African American or Hispanic (Teach for America 2001).

table 2-19.) The favorable job market in the nation after 1992 may account for some of the decline in graduate enrollment. For general workforce conditions that may influence enrollment in higher education, see chapter 3, "Science and Engineering Workforce." The increase in 1999 is mainly accounted for by the increased percentage of foreign students enrolling in U.S. graduate S&E programs. (See appendix table 2-20.)

Graduate Enrollment by Sex, Race/Ethnicity, and Citizenship

The long-term trend of women's increasing proportion of enrollment in all graduate S&E fields has continued during the past two decades, with significant differences by field. By 1999, women constituted 59 percent of the graduate enrollment in social and behavioral sciences and 43 percent of the graduate enrollment in natural sciences. In the same year, women constituted 37 percent of the graduate students in mathematics, 30 percent of the graduate students in computer sciences, and only 20 percent of the graduate enrollment in engineering. However, men are not as prevalent among underrepresented minority groups in NS&E fields; women in underrepresented minority groups have a higher proportion of graduate enrollment than women in other groups. For example, one-third of black graduate students in engineering and more than one-half of the black graduate students in natural sciences are women. (See text table 2-10.)

Graduate enrollment trends also differ by race and ethnicity. The proportion of total enrollment represented by white (majority) students in graduate S&E programs declined from 65 percent in 1975 to less than 53 percent in 1999. In contrast, the number of underrepresented minority students in graduate S&E programs has increased during the past two decades. However, the rate of increase has slowed from 6.5 percent in the 1986–92 period to 4.1 percent in the 1992–99 period. Underrepresented minorities, which make up almost 25 percent of the U.S. population, represent 9.3 percent of the students in graduate S&E programs in U.S. higher education. Asians/Pacific Islanders are well represented in advanced S&E education, constituting 4 percent of the U.S. population and 6.7 percent of the graduate students in S&E programs. (See appendix table 2-20.)

After a four-year decline (1993–96), the number of foreign students enrolling in U.S. graduate S&E programs turned around in 1997 and 1998 and increased sharply in 1999. The decline in foreign students from 1993 to 1996 (and the subsequent decline in foreign doctoral degree recipients in 1997–99) is partly explained by fewer Chinese students coming to the United States during the few years after Tiananmen Square and the Chinese Student Protection Act. Chinese student enrollment in the U.S. S&E graduate programs declined from 28,823 in 1993 to 24,871 in 1995 and then continued to increase in subsequent years. However, the number of graduate S&E students from India, South

Special New Programs

Some programs and institutions of higher education have supported recommended reforms.

Focusing on Learning Outcomes

Newly adopted accreditation guidelines for both the Accreditation Board of Engineering and Technology (2001) and the National Council for Accreditation of Teacher Education are based on outcome rather than simply on courses of study and admission criteria (Wise 2001).

Recent surveys of higher education institutions have included specific questions related to employer and general public satisfaction and student perception of their experience in terms of the number and quality of their contact with faculty, level of academic challenge, internships and study abroad projects, frequency of student group and community projects, signs of active and collaborative learning, and other factors (NGA Center for Best Practices 2001; PEW Forum on Undergraduate Learning 2000).

Increasing the Diversity of the S&E Workforce

The production of minority science and engineering bachelor's degrees from the first set of institutions involved in an NSF program aimed at increasing minority S&E students has increased from 3,900 in 1990 to 7,200 in 2000 (Dale 2001).

Incorporating Recent Advances in Teaching and Learning Into the Undergraduate Classroom

Many institutions are experimenting with creating learning communities to encourage S&E students to understand the basic concepts of the phenomena they are studying and to help each other learn. For example, on a single-course basis, a consortium of nearly 60 institutions has added student-led discussion workshops to their organic chemistry classes. Students meet in workshops, are handed observations from a specific chemical technique (e.g., infrared spectroscopy), and are asked to jointly analyze the results. They work in teams and are encouraged to engage everyone on the team in devising solutions. At one participating institution, the University of Rochester, where only 67 percent of organic chemistry students in the early 1990s earned the "C" necessary to enroll in more advanced chemistry courses, 79–82 percent of the students now earn a "C" or better. These results are mirrored throughout the consortium (Cox 2001).

One effort involving a related series of courses is aimed at increasing the retention of entering prescience and preengineering students at the University of Texas at El Paso. Students are assigned to a block of three linked courses (an English course, a mathematics course, and a seminar course with a science or engineering theme) featuring cooperative learning teaching techniques. Twelve percent more of the students in the cluster groups remained S&E majors (80 percent retained) compared with nonclustered students (68 percent retained) (Rothman and Narum 1999).

In response to the findings of research on learning and teaching, numerous efforts have been initiated to more actively involve students in classes. Examples range from course-specific efforts such as those of Eric Mazur, a physics professor at Harvard, to more universal approaches such as the adoption of problem-based learning techniques in all basic science courses at the University of Delaware. As much as one-third of Mazur's physics classroom time is devoted to consideration of conceptual questions related to the subject of the day. Mazur poses a challenging question to the class, students record their answers via computer, and the results are discussed, resulting in increased student interest and participation and an opportunity for the faculty to correct misconceptions as they occur. The University of Delaware finds that problem-based learning promotes active learning and connects concepts to applications. A real-life science-related problem is presented to students, who then work in groups to gather information from appropriate sources and develop a reasonable solution (The Boyer Commission on Educating Undergraduates 1998).

Augmenting Research Experiences for Undergraduates

Numerous universities are incorporating research experiences for either a distinct subset or all of their S&E majors. Summer opportunities for research included approximately 400 NSF Research Experiences for Undergraduates projects in the nation in 2000, serving about 4,000 undergraduates (NSF/EHR 2001b); research opportunities for students preparing to be teachers initiated as a joint project of the Department of Energy and the National Science Foundation (NSF/EHR 2001c); and programs supported by the Howard Hughes Medical Institute (2001).

To encourage a research-based approach to education in S&E, Rensselaer Polytechnic Institute has redesigned its large introductory courses, replacing lecture, recitation, and laboratory with a studio format taught in a specially designed facility by a single faculty member assisted by one graduate student and several undergraduates (The Boyer Commission on Educating Undergraduates 1998).

The University of Arizona is attempting to make research opportunities an integral part of each student's undergraduate experience through the introductory biology course, serving about 1,800 students per year. In addition, two undergraduate laboratory research experiences are offered, one in faculty laboratories at the University of Arizona and a followup experience in biomedical research abroad.

Text table 2-10.
Female enrollment in U.S. graduate S&E programs among racial/ethnic groups and foreign students, by discipline: 1999
(Percentages)

Race/ethnicity and citizenship	Total S&E	Natural sciences	Mathematics	Computer sciences	Social and behavioral sciences	Engineering
Total	41	43	37	30	59	20
White	44	44	37	25	60	19
Asian/Pacific Islander	42	49	44	38	63	25
Black	58	58	45	45	66	33
Hispanic	50	50	39	24	63	24
American Indian/Alaskan Native	52	49	60	32	62	28
Foreign students	30	37	35	30	45	18

NOTES: Foreign students include those on temporary visas only. Values are percentages of total enrollment for each subgroup within each field. Natural sciences include physics, chemistry, astronomy, and biological, agricultural, earth, atmospheric, and ocean sciences.

SOURCE: National Science Foundation, Science Resources Studies (NSF/SRS), *Graduate Students and Postdoctorates in Science and Engineering: Fall 1999,* NSF 01-315 (Arlington, VA, 2001).

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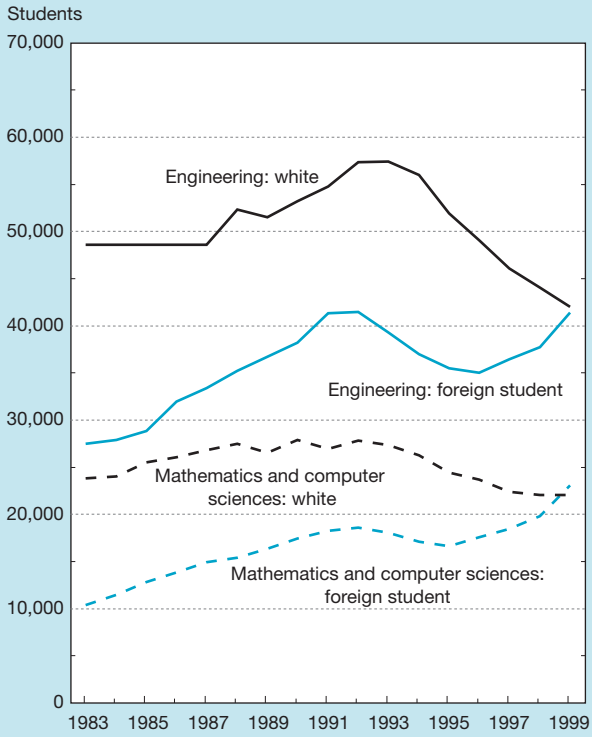
Korea, Taiwan, Indonesia, and Malaysia also declined in various years in the 1990s because of expanded opportunities for graduate education within their own countries or regional economies. (See appendix table 2-21.)

Despite the four-year decline, the longer term trend shows increasing enrollment of foreign graduate students in S&E fields in U.S. institutions. Evidence shows that foreign student enrollment also is increasing in other major host countries (the United Kingdom and France) and to other host countries (Germany and Japan). See "International Comparison of Foreign Student Enrollment in S&E Programs." The international trend may be driven by the desire for advanced training in S&E fields and employment opportunities in S&E careers. In 1999, this increasing foreign enrollment, coupled with a declining number of U.S. white (majority) students, resulted in an approximately equal number of white and foreign students in the U.S. graduate programs in mathematics, computer sciences, and engineering. (See figure 2-13.)

The NSF 1999 Survey of Graduate Students and Postdoctorates in Science and Engineering (NSF/SRS 2001a) shows that more than 100,000 foreign students were enrolled in U.S. S&E graduate programs. They represent a significant proportion of engineering (41 percent) and math and computer science (39 percent) students. Except for Canada, the 10 top countries of origin of foreign students to the United States are in the Asian region. Trends in enrollment from particular Asian countries and economies show a decline through most of the 1990s for students from Taiwan, a leveling off of students from South Korea, and an increasing number of students from China and India after a temporary drop. (See figure 2-14, appendix table 2-21, and "International Comparisons of Foreign Student Enrollment in S&E Programs" at the end of the chapter.)

Figure 2-13.
Trends in graduate enrollment in mathematics and computer sciences and in engineering: 1983–99



NOTE: White includes U.S. citizens and permanent residents; foreign student includes temporary residents only.

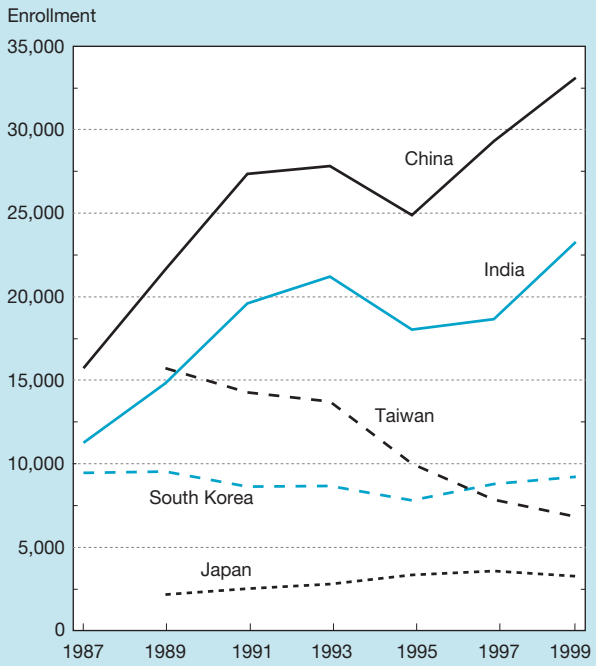
See appendix table 2-20. *Science & Engineering Indicators – 2002*

Master's Degrees

Overall Trends

Declining S&E degree trends at the master's level resemble those at the bachelor's level. The number of degrees earned in engineering, the most attractive major at the master's level, increased rapidly for more than a decade, peaked in 1994, declined for three consecutive years, and leveled off. The number of degrees earned in social sciences, psychology, and biological/agricultural sciences increased strongly in the 1990s

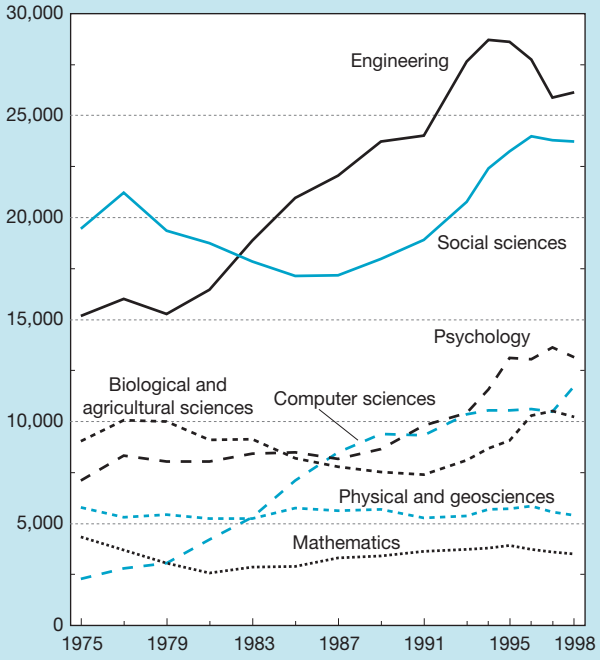
Figure 2-14.
Foreign student enrollment in U.S. S&E graduate programs, by selected countries and economies: 1987–99



NOTES: Data for 1999 are estimated based on the previous percentages of graduate students from each country who enrolled in S&E fields. Foreign students include only those on temporary visas.

See appendix table 2-21. *Science & Engineering Indicators – 2002*

Figure 2-15.
Master's degrees awarded in S&E, by field: 1975–98



NOTE: Geosciences include earth, atmospheric, and ocean sciences.

See appendix table 2-22. *Science & Engineering Indicators – 2002*

and leveled off in the past few years. The corresponding statistics for mathematics, physical sciences, and geosciences have remained stable during the past few decades. The number of degrees earned in computer sciences remained essentially flat for most of the 1990s; computer sciences is one of the few S&E fields that exhibited an increase in degrees earned in 1998. (See figure 2-15.)

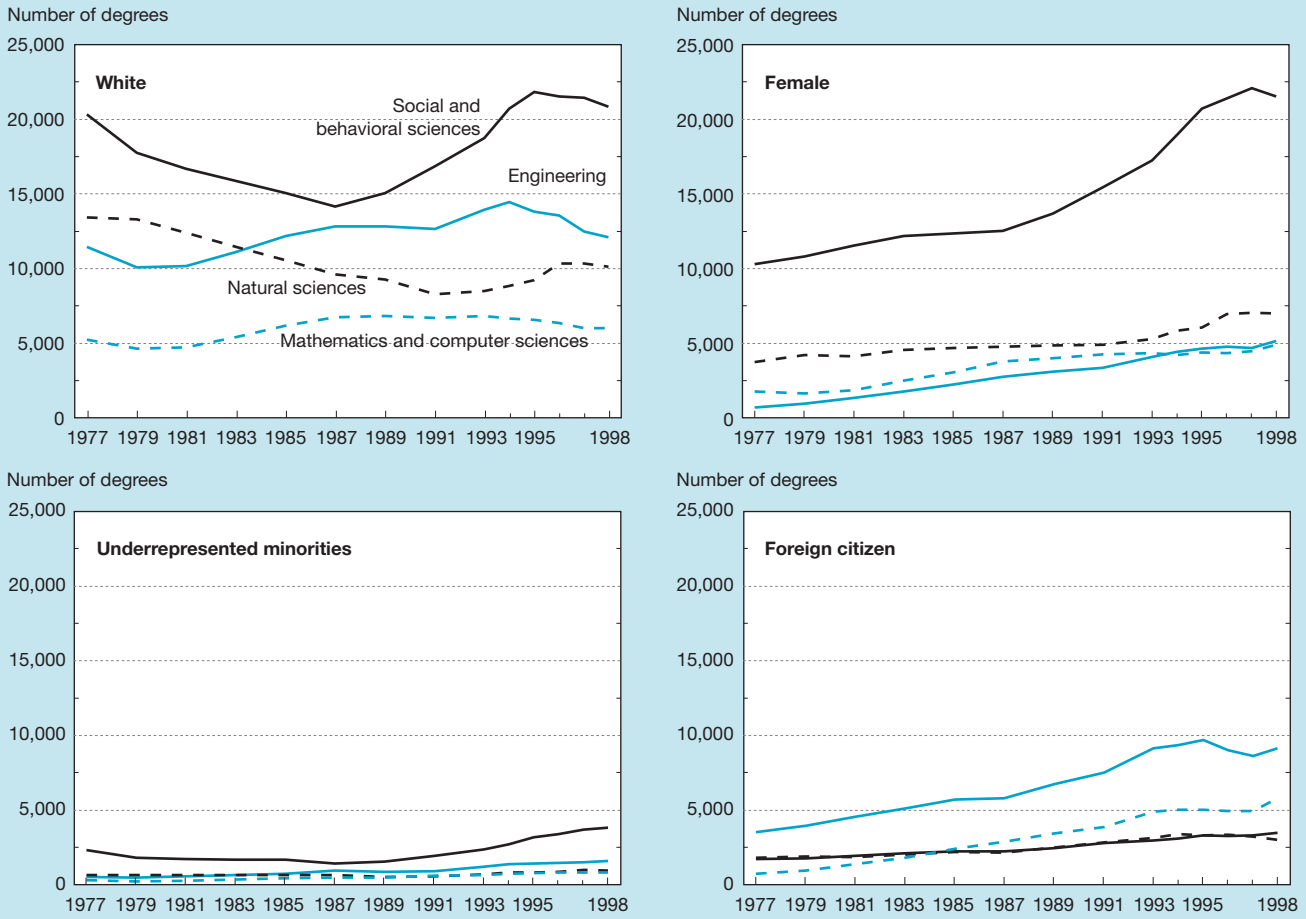
Master's Degrees by Sex, Race/Ethnicity, and Citizenship

Trends for men earning master's degrees differ slightly from trends for women. For men, growth in the number of degrees earned in biological and social sciences and psychology was more modest, and growth in computer sciences was stronger until 1996, when the number of degrees earned declined. Trends for women show continuously strong increases during the past two decades in biological and social sciences and psychology, modest increases in computer and physical sciences, and constant levels in mathematics, with a slight downturn in mathematics and physical sciences after 1996. (See appendix table 2-22.)

Trends also differ by race/ethnicity and citizenship. White students follow the overall trends, with increases in biological and social science, psychology, and computer science degrees earned in the 1980s, followed by steady decreases throughout the 1990s. In contrast, trends for Asian/Pacific Islander students show an increasing number of degrees earned in all S&E fields, particularly in computer sciences. S&E trends for blacks at the master's level show strong growth in the number of degrees earned in social sciences and psychology and modest growth in biological and computer sciences. Hispanic students also show strong growth in the number of degrees earned in social sciences and psychology, modest growth in biological sciences, and minor fluctuations in computer sciences. American Indians/Alaskan Natives earned an increasing number of degrees in social sciences and psychology, but the number of degrees earned in all other fields fluctuated around a low base. The number of degrees earned by foreign students increased in all S&E fields, particularly computer sciences, until 1993 and then leveled off or declined. Trends in broad fields are shown for selected groups in figure 2-16.

Among the new directions in graduate education are the creation of the new "terminal" master's degrees and the proliferation of professional certificate programs. Terminal master's programs provide the skills (often interdisciplinary) needed by professionals working in emerging S&E fields. Professional certificates that are approved by graduate programs include a coherent set of courses for a specialty, such as engineering management. The latter are amenable to distance delivery at corporate sites. See sidebar, "Terminal Master's Degree Programs."

Figure 2-16.
Master's degrees in S&E fields earned by selected groups: 1977–98



Underrepresented minorities = black, Hispanic, and American Indian/Alaskan Native

NOTES: Data are estimated for 1983. Natural sciences include physics, chemistry, astronomy, and earth, atmospheric, ocean, biological, and agricultural sciences. White and underrepresented minorities include U.S. citizens and permanent residents. Foreign citizen includes temporary residents.

See appendix tables 2-22 and 2-23.

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Doctoral Degrees

Overall Doctoral Trends

After a steady upward trend during the past two decades, the overall number of doctoral degrees earned in S&E fields declined in 1999. Trends differ by field. Degrees in biological sciences followed the overall pattern and declined for the first time in 1999. The number of degrees earned in engineering peaked in 1996 and declined for the next three years. This decrease in the number of engineering degrees earned is accounted for mainly by the decrease in the number of degrees earned by foreign students from 1996 to 1999. See "Doctoral Degrees by Citizenship." The number of degrees earned in psychology and social sciences increased slightly in the 1990s and leveled off in 1998–99. The number of degrees earned in the physical sciences and geosciences, mathematics, and computer sciences was stable in the 1990s and declined slightly in 1999. (See figure 2-17.)

Doctoral Degrees by Sex

At the doctoral level, the proportion of S&E doctoral degrees earned by women has risen considerably in the past three decades, reaching a record 43 percent in 1999. (See figure 2-18.) However, dramatic differences by field exist. In 1999, women earned 23 percent of the doctoral degrees awarded in physical sciences, 18 percent of those in computer sciences, and 15 percent of those in engineering. However, they earned more than 41 percent of the degrees awarded in biological and agricultural sciences and 42 percent of those awarded in social sciences. Women earned most of the degrees (66 percent) awarded in psychology.[4] (See appendix table 2-24.) The long-term trend of an increasing number of doctoral degrees earned by women halted in 1999, with slight decreases in biological and physical sciences and a leveling off in other S&E fields (NSF/SRS 2001d). (See appendix table 2-24.)

[4]See National Science Foundation, Division of Science Resources Studies, *Science and Engineering Doctorate Awards: 1999*, table 2, for percentages of doctoral degrees earned by women for detailed S&E fields in 1990 and 1999.

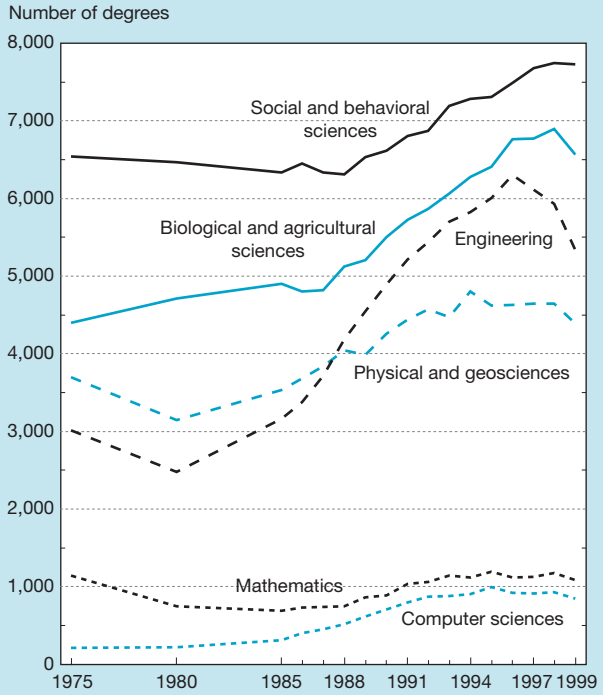
Terminal Master's Degree Programs

Terminal master's degree programs might be viewed as the science equivalents of master's degree programs in business administration (Littman and Ferruccio 2000). Although these programs have existed for many years, industrial and academic interest is growing in programs that prepare students to enter emerging science and engineering (S&E) fields (e.g., bioinformatics and computational chemistry) as skilled professionals. These programs tend to be broader than just one field and require skills in various disciplines.

The Sloan and Keck Foundations are supporting development of such programs to supply the growing S&E technical needs of industry, government agencies, and academic researchers and to answer the needs of students who do not want to go into clinical medicine or research careers but want to remain in science or mathematics (Tobias 2000). National data concerning how many of these programs exist or how many students participate in them will not emerge for several years. In 2000, the Sloan Foundation supported 17 such programs distributed among five universities, and at least 7 more programs distributed among three new university participants are planned for 2001.*

*For more information, see <http://www.sciencemasters.com>.

Figure 2-17.
Doctoral S&E degrees earned in U.S. universities, by field: 1975–99



NOTES: Data are in five-year increments for 1975–85, and one-year increments for 1985–99. Geosciences include earth, atmospheric, and ocean sciences.

See appendix table 2-24. *Science & Engineering Indicators – 2002*

Doctoral Degrees by Race/Ethnicity

In the past decade, the white (majority) population earned a slightly increasing number of doctoral degrees across most S&E fields, followed by a downturn in most fields in 1998–99. In the same period, underrepresented minorities also earned an increasing number of doctoral degrees across all fields, mainly in social, behavioral, and natural sciences. Their increases were from such a low base, however, that the number of doctoral degrees awarded to underrepresented minorities is barely visible on a graph that compares S&E degrees earned by various groups. (See figure 2-19.) The modest gains in the number of degrees earned in engineering, mathematics, and computer sciences continued in the 1990s until 1998, when the number of degrees earned in these fields turned slightly downward. Among Asians/Pacific Islanders who were citizens and permanent residents, the steep increases in the mid-1990s mainly reflect the Chinese foreign students on temporary visas shifting to permanent resident status from the 1992 Chinese Student Protection Act. The number of degrees earned by Asians/Pacific Islanders has since leveled off. (See appendix table 2-25.)

Doctoral Degrees by Citizenship

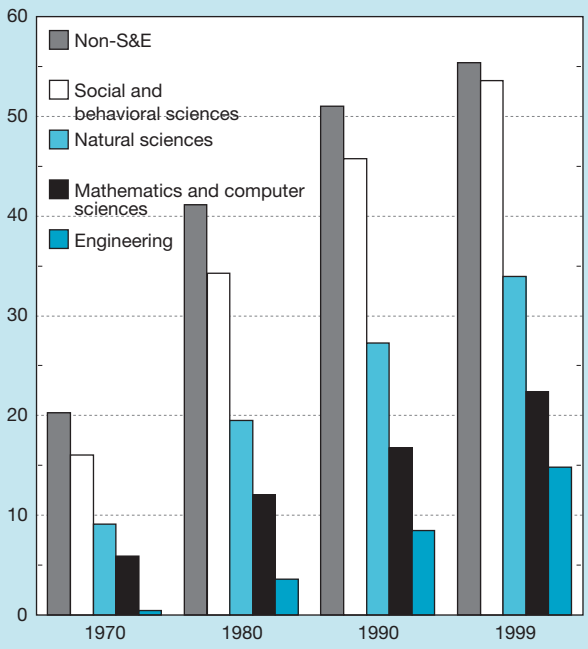
Each year from 1986 to 1996, the number of foreign students earning S&E doctoral degrees at universities in the United States increased; after that, this number of earned degrees dropped off. The number of such degrees earned by foreign students increased much faster (7.8 percent annually) than the number earned by U.S. citizens (2 percent annually). (See appendix table 2-26.) For example, the number of foreign students earning doctoral degrees in S&E increased from 5,000 in 1986 to almost 11,000 in the peak year of 1996, with declines each succeeding year.[5] During the 1986–99 period, foreign students earned 120,000 doctoral degrees in S&E fields. China is the top country of origin of these foreign students; almost 24,000 Chinese students earned S&E doctoral degrees at universities in the United States during this period (NSF/SRS 2001d).

The decline in S&E doctoral degrees earned by foreign students mirrors their declining enrollment in graduate S&E programs from 1993 through 1996. (See appendix table 2-20.) After this four-year drop-off in enrollment, the number of foreign graduate students stabilized in 1997 and increased in 1998 and 1999. (The number of foreign doctoral recipients may increase within the next few years if their graduate enrollment in U.S. institutions continues to increase.)

Foreign students earn a larger proportion of degrees at the doctoral level than any other degree level, more than one-third of all S&E doctoral degrees awarded. (See figure 2-20.)

[5]Numbers include students on both temporary and permanent visas but not naturalized citizens.

Figure 2-18.
Doctoral degrees earned by women in U.S. institutions, by field: 1970–99



NOTE: Natural sciences include physics, chemistry, astronomy, and earth, atmospheric, ocean, biological, and agricultural sciences.

See appendix table 2-24. *Science & Engineering Indicators – 2002*

Their proportion in some fields is considerably higher: in 1999, foreign students earned 47 percent of doctoral degrees awarded in mathematics and computer sciences and 49 percent of those awarded in engineering.

Doctoral Reform

The need for reform of doctoral education has been widely noted and discussed. In 1995, the Committee on Science, Engineering, and Public Policy (COSEPUP) recommended broadening the education of doctoral students beyond research training. Because more than one-half of all doctoral recipients obtain nonacademic employment, COSEPUP recommended that doctoral students acquire an education in the broad fundamentals of their field, familiarity with several subfields, the ability to communicate complex ideas to nonspecialists, and the ability to work well in teams (COSEPUP 1995). Subsequently, professional societies and leading educators encouraged the expansion of COSEPUP recommendations beyond physical sciences and engineering to include all graduate education.

NSF responded to COSEPUP's recommendations by funding universities to establish Integrative Graduate Education and Research Traineeship (IGERT) programs. Such awards enable universities to offer stipend support to graduate students to engage in research in emerging multidisciplinary areas of S&E (NSF/EHR 2001a). From 1997 to 2000, NSF granted university faculties a total of 57 awards in the IGERT program.

Current research on doctoral education shows that doctoral students' high level of interest and belief in the possibility of a faculty career persist even though the number of doctoral degrees granted far exceeds available tenure-track positions. See sidebar, "At Cross Purposes."

Current efforts focus on how to "re-envision the Ph.D." to meet the needs of society in the 21st century and how to effect reforms without lengthening the time to achieve a degree. The re-envisioning project provides a forum for national dialog on doctoral reforms among key stakeholders: research- and teaching-intensive institutions, doctoral students, agencies that fund and hire doctoral recipients, disciplinary societies, and education associations. A recent workshop composed of many such stakeholders agreed on six themes for doctoral reforms:

- shorten time to degree acquisition,
- increase underrepresented minorities among doctoral recipients,
- improve the use of technology for research and instructional purposes,
- prepare students for a wider variety of professional opportunities,
- incorporate understanding of the global economy and international scientific enterprise, and
- provide doctoral students with an interdisciplinary education.

The project also collects and disseminates promising practices for doctoral education that are submitted by individual departments (Nyquist and Woodford 2000). See also chapter 3 on "Science and Engineering Workforce" for employment prospects of doctoral recipients by field and the sidebar, "International Efforts in Doctoral Reform," at the end of this chapter.

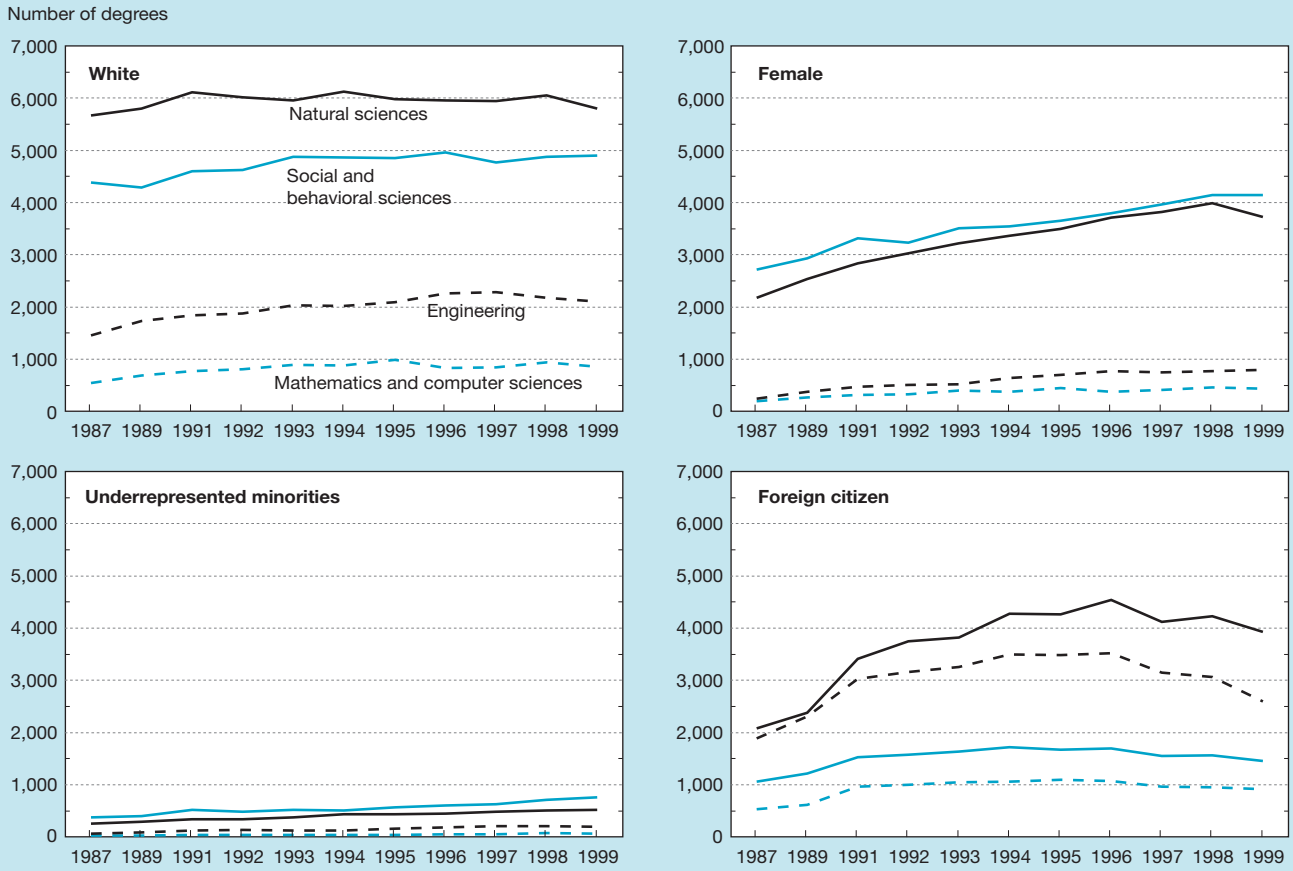
Financial Support for S&E Graduate Education

U.S. higher education in S&E fields has traditionally coupled advanced education with research. This coupling is reflected by the various forms of financial support for S&E graduate students, particularly those pursuing doctoral degrees. Support mechanisms include fellowships, traineeships, research assistantships (RAs), and teaching assistantships (TAs).

Sources of support include Federal agency support, non-Federal support, and self-support. See sidebar, "Definitions and Terminology," for fuller descriptions of both mechanisms and sources of support. Most graduate students, especially those who pursue doctoral degrees, are supported by more than one source and one mechanism during their time in graduate school; some graduate students may even receive support from several different sources and mechanisms in any given academic year.

This section describes both sources and mechanisms of financial support. During the 1990s, the distribution of different mechanisms of support stabilized after the importance of RAs increased during the 1980s. The increase was offset

Figure 2-19.
Doctoral degrees in S&E fields earned by selected groups



NOTES: Natural sciences include physics, chemistry, astronomy, and earth, atmospheric, ocean, biological, and agricultural sciences. Underrepresented minorities include black, Hispanic, and American Indian/Alaskan Native. White and under-represented minorities include U.S. citizens and permanent residents. Foreign citizen includes those on either permanent or temporary visas.

See appendix tables 2-24, 2-25, and 2-26.

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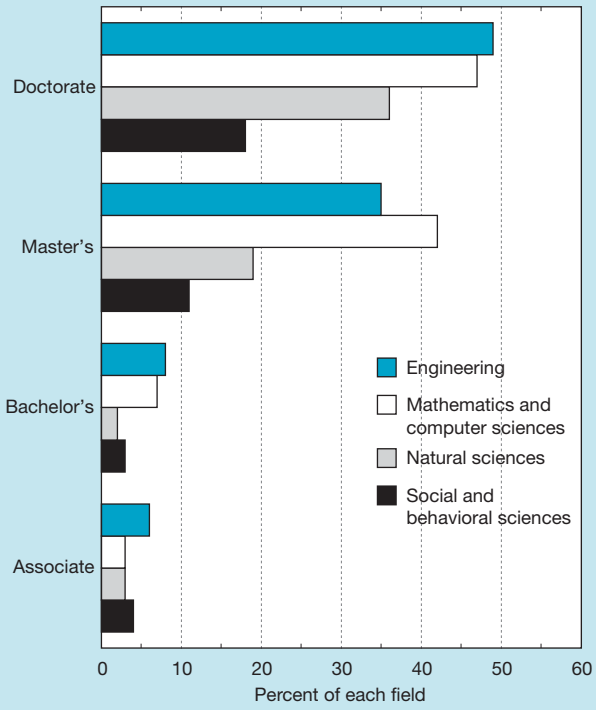
by a reliance on traineeships and self-support. The relative stability in the proportion of different mechanisms of support in the 1990s holds for both federally and nonfederally supported students. Federal support is found predominantly in the form of RAs, which represent 66 percent of all Federal support. However, Federal support through fellowships increased slightly in the 1990s, from 9 percent in 1989 to 11 percent in 1999. For students supported through non-Federal sources, TAs are the most prominent mechanism (41 percent), followed by RAs (30 percent). (See appendix table 2-27.)

Primary mechanisms of support differ widely by S&E fields of study. For example, students in physical sciences are supported mainly through RAs (42 percent) and TAs (41 percent). RAs also are important in engineering (42 percent) and earth, atmospheric, and ocean sciences (41 percent). In mathematics, however, primary student support is through TAs (57 percent) and self-support (17 percent). Students in social sciences are mainly self-supporting (41 percent) or receive TAs (22 percent). (See appendix table 2-28.)

The Federal Government plays a significant role in supporting S&E graduate students in some selected fields and mechanisms and an insignificant role in others. For example, Federal traineeships represent approximately two-thirds of all such support, almost one-half of all RAs, and one-quarter of all fellowships. The percentage of Federal traineeships is even greater in physical and biological sciences and in chemical engineering, and the Federal Government supports most RAs in physical sciences. In contrast, the Federal Government is not a significant source of support for graduate education in social sciences, psychology, and mathematics. (See appendix table 2-29.)

The National Institutes of Health (NIH) and NSF support most of the S&E graduate students whose primary support comes from the Federal Government, 17,000 and 14,000 students, respectively. Trends in Federal agency support of graduate students show a considerable increase in the proportion of students supported primarily by NIH, from less than 22 percent in 1980 to 29 percent in 1999. The proportion of graduate students receiving Federal support primarily by NSF has

Figure 2-20.
S&E degrees earned by foreign students within each field, by level: 1998–99



NOTES: Doctoral degree data are for 1999; all others are 1998 data. At the doctoral level, foreign students include both permanent and temporary residents; all other levels include only temporary residents. Natural sciences include physics, chemistry, astronomy, and earth, atmospheric, ocean, biological, and agricultural sciences.

See appendix tables 2-15, 2-17, 2-23, and 2-26.

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At Cross Purposes

A recent survey of doctoral programs queried students in three areas: their goals, the effectiveness of doctoral programs in preparing students for careers within and outside academia, and the level of student satisfaction with their programs (Golde and Dore 2001).

The findings revealed that most students interviewed were interested in a faculty job in the future. When questioned about preparation for various aspects of their future career, 65 percent of the students indicated that they were prepared by their program to conduct research; fewer felt prepared to publish their research findings (43 percent) or collaborate in interdisciplinary research (27 percent). Relatively few students (38 percent) reported that they were encouraged to take part in nonacademic job search workshops.

More than half of all doctoral students had opportunities to improve their teaching skills, but these opportunities varied greatly among the disciplines surveyed. Training courses for teaching assistants were least likely in chemistry (28 percent) and molecular biology (30 percent).

Overall, students reported being satisfied with their decision to pursue doctoral degrees; however, they were less certain about the details of pursuing a doctoral education in regard to their daily lives. They entered the program without having a good idea of the time, money, clarity of purpose, and perseverance that doctoral study requires. Once enrolled, they received little guidance on how to complete the process successfully.

increased from 18 to 21 percent in the past two decades. In contrast, the Department of Defense provided primary support for a declining proportion of students funded primarily by Federal sources: 17 percent in 1988 and 12 percent in 1999. (See appendix table 2-30.)

Support Mechanisms for Doctoral Students

For doctoral students, support mechanisms can be classified by sex, race/ethnicity, and citizenship. For men, the leading support mechanism is RAs, followed by personal sources. For women, the leading support mechanism is personal sources, followed by fellowships. Foreign doctoral students serve as S&E research and teaching assistants and are more likely to have RAs and TAs as their primary sources of support. For example, more than 80 percent of the Chinese doctoral degree recipients in the United States from 1988 to 1996 reported in the U.S. Survey of Earned Doctorates (SED) that they were supported by university RAs,[6] and more than 50 percent reported financial support from TAs (NSF/SRS 2001a). U.S. citizens are more likely to have personal sources of support. For underrepresented minorities, however, fellowships are the primary source of support. (See appendix table 2-31.)

Stay Rates of Foreign Doctoral Recipients

Historically, approximately 50 percent of foreign students who earned S&E degrees at universities in the United States reported that they planned to stay in the United States, and a smaller proportion had firm offers to do so (NSF/SRS 1998). In 1990, for example, 45 percent of all foreign S&E doctoral degree recipients planned to remain in the United States after completing their degree, and 32 percent had received firm offers. As a result of the strong economy and employment opportunities of the 1990s, however, these percentages increased significantly. By 1999, more than 72 percent of foreign doctoral recipients in S&E fields planned to stay in the United States, and 50 percent accepted firm offers to do so. (See figure 2-21 and appendix table 2-32.)

The number of S&E doctoral degrees earned by foreign students declined after 1996, but the number of students who had firm plans to remain in the United States declined only slightly from its 1996 peak. Each year from 1996 to 1999,

[6] Much of the funding for university RAs is derived from Federal grants to universities.

Definitions and Terminology

Fellowships are competitive awards (often from a national competition) given to students for financial support of their graduate studies.

Traineeships are educational awards given to students selected by the institution.

Research assistantships are given to students whose assigned duties are devoted primarily to research.

Teaching assistantships are given to students whose assigned duties are devoted primarily to teaching.

Other mechanisms of support include work-study programs, business or employer support, and support from foreign governments that is not in the form of a previously mentioned mechanism.

Self-support is derived from any loans obtained (including Federal loans) or from personal or family contributions.

Federal support comes from Federal agencies; examples are the GI bill and tuition paid by the Department of Defense for members of the Armed Forces.

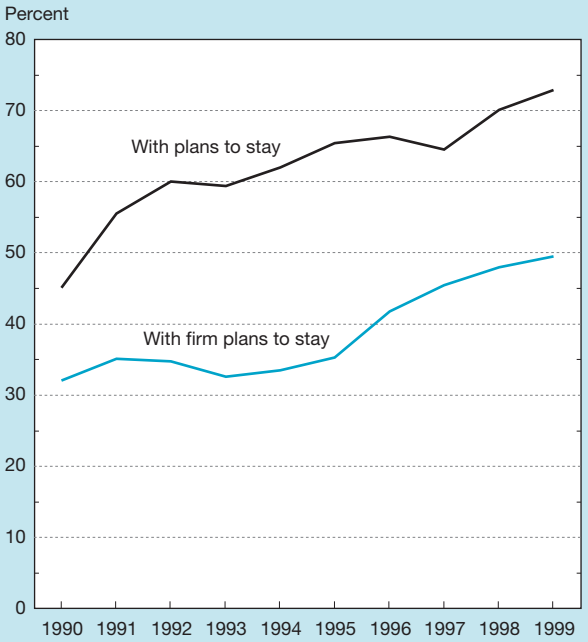
Non-Federal support comes from the student's institution of higher education, state and local government, foreign sources, nonprofit institutions, or private industry.

more than 4,000 foreign doctoral recipients had firm offers to remain in the United States at the time of degree conferral. (See figure 2-22.) These firm offers were mainly for postdoctorate appointments and industrial employment in research and development (R&D).

Foreign doctoral students' plans to stay in the United States differ by region of origin. Those from East and South Asia receive the highest number of doctoral degrees by far and constitute the highest percentage of students who plan to stay in the United States. (See text table 2-11.) Countries within regions also differ significantly. In Asia, China and India have higher-than-average firm stay rates in the United States, and South Korea and Taiwan have lower-than-average firm stay rates. In North America, Mexico has a far lower stay rate than Canada. The United Kingdom has the highest stay rate among European countries; in 1999, 79 percent planned to stay in the United States after earning their doctorate in S&E fields, and 62 percent had firm offers to do so. (See figure 2-23.)

After 1996, the number of foreign doctoral degree recipients from China, Taiwan, and India with plans to stay in the United States declined slightly, even though the proportion that planned to stay increased. Because the number of S&E doctoral degrees earned by these groups decreased after 1996, the net result was that fewer remained in the United States. (See figure 2-24.)

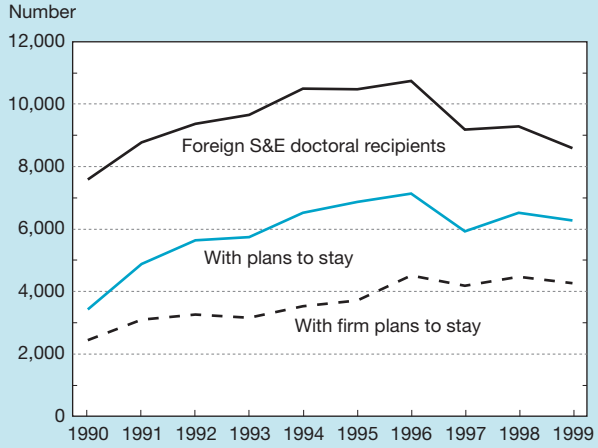
Figure 2-21.
Percentage of foreign S&E doctoral recipients with plans to stay in United States: 1990–99



NOTE: Data include foreign doctoral recipients with either permanent or temporary visas.

See appendix table 2-32. *Science & Engineering Indicators – 2002*

Figure 2-22.
Foreign S&E doctoral recipients with plans to stay in United States: 1990–99



NOTE: Foreign doctoral recipients include those with either permanent or temporary visas.

See appendix table 2-32. *Science & Engineering Indicators – 2002*

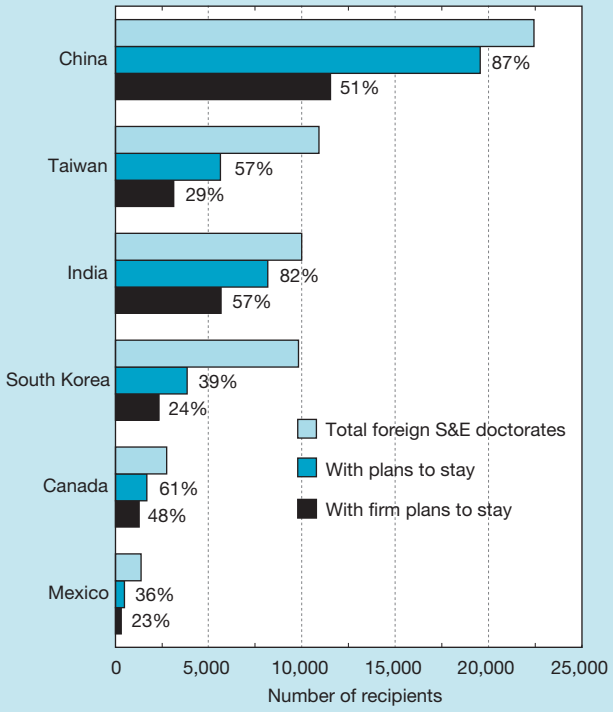
The SED data on stay rates can be used to indicate immediate reverse flow of foreign doctoral recipients. Those with no plans to stay in the United States may be planning an immediate return to their home country or to another country in the region. For example, Chinese doctoral recipients with no plans to stay in the United States may be hired by a research

Text table 2-11.
Foreign S&E doctoral recipients with plans to stay in the United States, by region: 1990–99

Region	Total	With plans to stay		With firm plans to stay	
		Number	Percent	Number	Percent
All regions	93,682	58,553	62.5	36,327	38.8
East/South Asia	57,609	39,154	68.0	23,932	41.5
West Asia	8,757	4,676	53.4	2,548	29.1
Pacifica/Australia	2,075	986	47.5	627	30.2
Africa	4,464	2,100	47.0	967	21.7
Europe	11,698	7,260	62.1	5,191	44.4
North/South America	9,079	4,377	48.2	3,062	33.7

See appendix table 2-32 for countries within each region. *Science & Engineering Indicators – 2002*

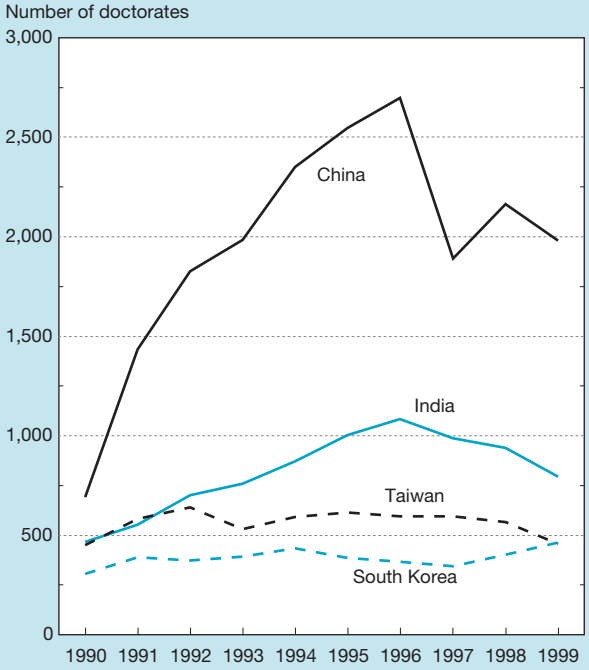
Figure 2-23.
Foreign S&E doctoral recipients with plans to stay in the United States, by place of origin: 1990–99



NOTE: Foreign doctoral recipients include those with either permanent or temporary visas.

See appendix table 2-32. *Science & Engineering Indicators – 2002*

Figure 2-24.
U.S. S&E doctoral recipients from selected Asian countries and economies with plans to stay in the United States: 1990–99



NOTE: Foreign doctoral recipients include those with either permanent or temporary visas.

See appendix table 2-32. *Science & Engineering Indicators – 2002*

institute in China or Singapore. The rate of return of S&E doctoral recipients from universities in the United States differs by country of origin. Mexico and Brazil have the highest reverse flow; India and China have the lowest. (See text table 2-12.)

Recently, the Social Science Research Council surveyed the rates of return of African Ph.D. recipients trained in U.S. and Canadian universities between 1986 and 1996. The survey found that 63 percent of these recipients were employed in their home country or a neighboring African country by 1999.[7] The factors that correlated with returning home were the home country of the degree holder, field of study, and type of funding for

[7]SED shows that 64 percent of African doctoral recipients planned to stay in the United States; however, because many were in biological sciences, they may have stayed for a postdoctorate for a few years and then returned to Africa. SSRC findings are relatively consistent with Finn's research on stay rates several years after Ph.D. attainment (Finn 1999). Finn's work shows that about 44 percent of African doctoral recipients were working in the United States several years after receiving their Ph.D.

Text table 2-12.
Foreign S&E doctoral recipients who returned home, by place of origin, selected countries and economies

Location of origin	Total recipients	Percentage who returned home
United Kingdom (1998)		
China	208	59
Malaysia	145	99
Germany	146	57
Greece	118	64
Iran	127	89
United States	80	75
Turkey	124	100
Canada	59	71
Taiwan	82	95
Ireland	61	45
United States (1999)		
China	2,187	10
India	888	10
South Korea	738	37
Taiwan	732	38
Canada	283	28
Turkey	186	41
Germany	179	35
Mexico	158	69
Brazil	156	69
United Kingdom	141	21

NOTES: U.S. data are foreign students with no plans to stay in the United States. Foreign students include those on either permanent or temporary visas.

SOURCES: Higher Education Statistics Agency, First Destination Survey of 1998 Doctoral Recipients, unpublished tabulations, 2001; and appendix table 2-32. *Science & Engineering Indicators – 2002*

graduate study. Economic opportunities, political stability, and institutional conditions for establishing a professional career correlated with high return rates. The fields of agricultural and biological sciences, which receive high funding priorities in some African countries, also correlated with high return rates (Pires, Kassimir, and Brhane 1999).

Foreign doctoral recipients in S&E who remain in the United States represent a potential "brain drain" from their country of origin, but they also have an opportunity for enhanced research experience before returning home. Reverse flow back home is increasing for countries with increasing S&E employment in higher education and research institutes. Little is known of the broader diffusion of S&E knowledge by foreign doctoral recipients who remain in the United States through activities such as cooperative research, short-term visits, and networking with scientists at home and abroad. See sidebar, "Reverse Flow."

Increasing Global Capacity in S&E

This section places data from the United States in an international context, including comparisons of bachelor's (first university) degrees, participation rates in S&E degrees, doctoral degrees, the level of foreign student enrollment, and the percentage of foreign students earning S&E doctoral degrees in major host countries. Information is provided on reforms to improve the quality of expanded doctoral programs in Europe and Asia and the stay rate and return flow of foreign doctoral recipients in a few other major host countries (the United Kingdom and France).

In regard to doctoral degrees, the proportion of S&E degrees earned outside the United States is shifting, which may eventually translate into a corresponding shift in research capacity, scientific output, and innovative capacity. See chapter 4, "U.S. and International Research and Development: Funds and Alliances," and chapter 5, "Academic Research and Development." The United States needs to devise effective forms of collaboration and information exchange to benefit from, and link to, the expanding scientific capabilities of other countries and regions. For example, increased international coauthorship may indicate that the United States is staying in touch with expanded research abroad. See "Scientific Collaboration" in chapter 5.

International Comparison of First University Degrees in S&E Fields

In 1999, more than 2.6 million students worldwide earned a first university degree in science or engineering.[8] (Note that the worldwide total includes only countries for which recent data are available, primarily the Asian, European, and American regions, and is therefore an underestimation.) Approximately 900,000 degrees were earned in fields within each of the broad categories of natural sciences, social and behavioral sciences, and engineering. (See appendix table 2-18.)

From among reporting countries, more than 1.1 million of the 2.6 million S&E degrees were earned by Asian students at Asian universities. Students across Europe (including Eastern Europe and Russia) earned almost 800,000 first university degrees in S&E fields. Students in North America earned more than 600,000 S&E bachelor's degrees. Students in Asia and Europe generally earn more first university degrees in natural science and engineering (NS&E) than in social sciences, whereas the converse is true for students in North America. (See figure 2-25.)

Trend data for bachelor's degrees show that the number earned in the United States remained stable or declined in the 1990s in all fields except psychology and biology. The number of engineering degrees earned in the United States declined from 1986 to 1991, remained nearly stable at the 1991 level for several years, and declined again in 1998. The number of computer science degrees declined from 1986 to 1990, remained essentially flat throughout the 1990s, and increased in 1998. In contrast, trend data available for selected Asian countries show strong growth in degree production in all S&E

[8] A first university degree refers to the completion of a terminal undergraduate degree program. These degrees are classified as level 5A in the International Standard Classification of Education, although individual countries use different names for the first terminal degree (for example, *laureata* in Italy, *diplome* in Germany, *maitrise* in France, and *bachelor's degree* in the United States and in Asian countries).